



Fermilab

TM-950-A
2914.000

NEUTRINO AREA IMPROVEMENTS FOR 500 GeV OPERATION

February 1980

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A. INTRODUCTION

In the spring-summer shutdown of 1980 the Neutrino Department will begin a series of improvements to the NØ beam line and the N7 hadron beam line. The purpose of this report is to describe these improvements and to describe other improvements which are proposed for subsequent fiscal years.

There are eight steps in this improvement plan. They are:

- (i) NØ Muon Shield Improvement
- (ii) N7 Relocation
- (iii) Neuhall Extension
- (iv) N3 Beam-Line Modifications
- (v) N5 Beam Line Improvements
- (vi) Switchyard Enclosure G2 Modification
- (vii) Target Station for a Prompt Neutrino Source
- (viii) Neutrino Flux Monitoring

Except for the N7 relocation, which is forced by the NØ muon-shield improvement, these projects are not dependent on each other and can be done independently. The primary thrust of these improvements is to maintain the vitality of the 400-GeV program and to make the Neutrino Area an efficient user in the 500-GeV Energy Saver program. These improvements are not in any way a part of the 1000-GeV Tevatron II program, but they are all compatible with the plans for Tevatron II. The improvements for 1000 GeV are also discussed in Section K of the report.

The most important improvement is the hardening of the muon shield. At primary energies over 350 GeV, muons penetrate the NØ shield and swamp the sensitive detectors in the Wonder Building.

Because the steel used to harden the muon shield occupies space presently used by the N3/N5 beamlines, it will be necessary to relocate the N7 beam line. The most sensible way to do this that is compatible with long-range plans is to relocate the entire N7 beam pipe between NeuHall and Enclosure 103. The N7 beam is used to transport primary protons to a production target that serves as a source of secondary particles for the N3 beam, which feeds the 30-in. chamber, and the N5 beam, which serves as a hadron calibration beam for the neutrino detectors in Lab E, Lab B, and Lab C. The production target for the N3 and N5 beams will be moved from Enclosure 100 to a modified Enclosure 103. The optics of the N3 beam will be modified in order to meet the requirements of the 30-in. experiments E565/E570 and E597.

The Laboratory plans to schedule in February 1981 a neutral-current experiment, E-594, and two 30-in. hybrid bubble-chamber experiments, E565/570 and E597. This will be the first opportunity for these experiments to take data. At the same time, it is planned to complete the Cal Tech-Fermilab-Rockefeller-Rochester Neutrino Experiment, E616. This important program can be scheduled only if the NØ dichromatic beam and the N7 hadron beam can be operated simultaneously. Because the magnets in the present dichromatic beam block the transmission of the N7 beam, simultaneous operation of these beams is not possible. By extending NeuHall southward 100 m to existing Enclosure G-3, it

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will be possible to deflect the N7 beam around the present Neutrino target tube, thereby making its operation independent of the type of target train. All the aforementioned changes will be initiated in the 1980 spring-summer shutdown. The completion of the Neuhall Extension and the NØ shield upgrade is scheduled for September 15, while the N7 relocation is scheduled to be completed by November 1.

Besides allowing independent operation of the N7 and NØ beams, the Neuhall extension will allow the use of a 750-GeV dichromatic train, as well as a 350-GeV train that is more reliable than the present one. These new trains will be designed so that the primary proton beam can be dumped on a proper dump rather than in one of several magnets. The NØ target tube constrains the length of the dichromatic train to 65 m, which is too short to permit the use of dumps which are separate from the magnets. The 100-m extension will permit the use of dichromatic trains which are 150 m long. A longer dichromatic train with proper dumps will reduce radiation exposures to the people in the Neutrino mechanical group who service the train. It will also increase the reliability of the train since the 1.2 mJ of energy which the primary beam dumps in magnets every 8 sec will be dumped in a beam dump designed to absorb this power. It is expected that by 1982 the reliability of the present 350-GeV/c dichromatic train will have been seriously compromised by radiation damage. A decision to rebuild this train will be deferred until after the February 1981 run. The construction of a 750-GeV dichromatic train will begin in 1981, because it is expected that the train could be used in late 1982 or 1983 with the Tevatron.

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In 1981 three additional improvements will be made. Enclosure G-2 in the switchyard will be modified in order to allow more flexible use of the NØ, N7, and N1 beams, as well as to provide an enclosure for the bypass beam to the bypass beam dump. The N5 beam will be moved westward into the NØ earth shield downstream of the Wonder Building in order to provide sufficient shielding to transport primary protons to Enclosure 113. Additional modifications will be made to the N3 beam so that a more intense \bar{p} flux per incident proton can be obtained for E-597. The same changes to N3 will lead to a purer K^+ beam for E-565.

A proposal to build an enclosure for a prompt neutrino source approximately 120 m upstream of Lab E is in preparation. The enclosure is being designed to contain a high-intensity high-density dump (10^{12} protons/pulse) that can serve as a source of τ neutrinos and e neutrinos for the detectors in Lab E (E-616), Lab B (15 ft. chamber) and Lab C (E-594). The location of these improvements is shown in Figures 1 and 2.

The subsequent sections of this report describe the improvements and their estimated costs and schedules in detail. The costs are summarized in Section J and Section K describes some future options after the eight projects described here are completed.

B. THE NØ MUON SHIELD

1. Description of the Upgrade of NØ Muon Shield

As discussed in the introduction, the primary beam energy has been limited to 350 GeV whenever experiments that use a wide-band neutrino beam (single horn and triplet) were performed in the Wonder Building. In 1978-1979, two extremely successful experiments, E-253 and E-531, were performed here. E-253 was a measurement of the very rare process $\nu + e^- \rightarrow \nu + e^-$ by VPI, Oxford, Maryland, and Beijing. E-531 was the first experiment to observe a sufficient number of charmed-particle decays in an emulsion to be able to measure the D^+ and D^0 lifetimes. The E-531 detector was built by a collaboration of Ohio State, Fermilab, McGill, Ottawa, Toronto, Aichi, Kobe, Korea, Nagoya, Okayama, Osaka, Tokyo and Yokahama. When it was attempted to run these experiments with 400-GeV primary protons, unacceptably high muon backgrounds were encountered. This was particularly unfortunate, because both experiments would have benefited significantly from the more intense flux of neutrinos produced from 400-GeV protons.

The result of E-253 was reduced in significance by the absence of a reliable measurement of the total neutrino flux. The Swiss-cheese-like voids in the present earth shield make it impossible to use the muon flux in the shield as a monitor of the absolute neutrino flux. Because of this experience and other examples like it, the Laboratory plans to rebuild the shield in time for the next major run of Wonder Building experiments, now scheduled for the summer-fall running period of 1980.

A significant shortcoming of the Fermilab wide-band beam neutrino experiments in general has been the absence of absolute cross section measurements. The present shield because of the voids and other inhomogenities, varies in a complicated way as a function of the displacement from the NØ beam center. As a result, monitoring of the muon flux in the shield is of little value. This fault was recognized in 1972, but it has not been possible to make changes until now because a three-month down-time is needed to carry out the modifications. CERN, because it has a homogeneous shield, is able to use the muon flux in the shield as a means of obtaining neutrino flux measurement with good success.

In order to make a shield that has the desirable properties noted above, it will be necessary to demolish the east half of Enclosure 101, which forms a 1.5-m x 2.1-m x 50-m void in the earth shield. One of the connecting tunnels between the east and west halves of Enclosure 101 will be retained as a muon flux monitoring station. A small pit will be dug in the linking tunnel to provide space for a 1.5-m x 1.5-m muon flux monitor, which can be located symmetrically with respect to the NØ beam center.

The steel shield will begin just downstream of Enclosure 100 and will extend to a point 150 m further downstream. Steel will also be placed inside Enclosure 100 at an appropriate time in the future. The 150-m shield will have an approximately square cross section of 3.5-m x 3.5-m; the steel stacked inside Enclosure 100 will be about 2-m square and 30-m long. The overall mass of the steel shield will be 16,000 tons. Some 11,000 tons of steel are in the process of being transferred from Argonne to Fermilab as a result of the decommissioning of the ZGS.

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Approximately 4,500 tons of steel that is buried just upstream of the Wonder Building will be moved from that location to Enclosure 100. The remainder of the steel for this shield will be armor plate that Fermilab has obtained earlier.

The 16,000T shield can be easily upgraded by adding another 11,000T of steel to this shield. When the Tevatron becomes operational, the Wonder Building will no longer be useful. For that reason it will be demolished and replaced with shielding. It should be noted that detectors in Labs E, B, and C are shielded by an additional 500 m of earth shielding downstream of the Wonder Building. A complete discussion of the Tevatron shield has been given by S. Mori¹.

2. NØ Muon Shield Upgrade Costs and Time Schedule

The scope of the project includes: 1) moving 11,000T of steel from Argonne to Fermilab, 2) mining 4,500T of steel presently in the beam upstream of the Wonder Building and its incorporation into the downstream portion of the steel shield, 3) demolition of the east half of Enclosure 101 and construction of a 50-m extension of Enclosure 103 for the N7 beam, 4) modification of one of the cross tunnels that link the east and west halves of Enclosure 101 so that a muon flux monitor may be installed at a later date.

The costs of the project are separated into operating costs and Accelerator Improvement Costs (AIP). Operating funds will be used to remove beam-line magnets, instrumentation, control cables, water-cooled bus, and shielding from the enclosures prior to making the enclosures accessible to the contractor responsible for the modifications. Accelerator Improvement funds will be

used for modifying existing enclosures. Following the completion of the enclosure modifications, most of the equipment will be reinstalled in the enclosures. The remainder of the equipment will be used elsewhere in the Laboratory. Operating funds will be used to move portions of the NØ earth shielding to a location adjacent to the NØ beam. Accelerator Improvement funds will be used to construct the 16,000T steel shield. After completion of the steel shield, operating funds will be used to move the earth shielding back into the NØ beam.

A cost estimate is given in Table I.

Table I

NØ Muon Shield Hardening Costs

1.	FY80 Operating Costs Related to Site Preparation	
1.1	Removal of Equipment from Enclosure 101 to N 2.5 Service Building	25K
1.2	Removal of earth shielding from NO beam between enclosure 100 and Batavia Road and restoration after installation steel shield	150K
1.3	Removal of 4500 tons of blooms, and ingots from in front of the Wonder Building to the steel staging area	155K
1.4	Relocation of Enclosure 100 target system in Enclosure 103.	<u>25K</u>
	Total FY80 Operating Costs	355K
2.	Accelerator Improvement Costs (1979 AIP -)	
2.1	EDIA	50K
2.2	Transportation of 11,000 tons of steel from Argonne to FNAL (steel staging area)	175K
2.3	Construction of the steel shield and of concrete support pads	200K
2.4	Modifications to Enclosure 101 and 103	<u>275K</u>
	Total FY79 AIP Costs	700K

The time schedule for this construction is given in Table II.

Table II

NØ Muon Shield Upgrade-Time Schedule

1.	Begin project, remove equipment from 101 and prepare site.	June 1, 1980
2.	Begin the removal of earth shielding from the NØ beam between 100 and 101. Modification of 101 begins.	June 11, 1980
3.	Steel placement begins.	June 25, 1980
4.	Begin modification of Enclosure 103.	July 15, 1980
5.	Beneficial occupancy of 101.	July 21, 1980
6.	Beneficial occupancy in modified Enclosures 103.	August 20, 1980
7.	Steel placement of first 12,000T complete, begin the replacement of the earth shielding.	August 20, 1980
8.	Complete the removal of the steel in front of the Wonder Building and install in shield.	Sept. 17, 1980
9.	Earth shield restoration at a stage that permits beam in the NØ line.	Oct. 1, 1980
10.	Complete the restoration of the earth shield.	Nov. 1, 1980

C. N7 RELOCATION

1. Description of N7 Relocation

In order to construct a homogeneous steel shield in the NØ beam, the N7 primary proton beam line, which is used to illuminate the production target for the N3 and N5 secondary hadron beams, must be relocated outside the region occupied by the steel. This will be accomplished as shown in Figure 1. The N7 beam will be bent to the east by 5 mrad in NeuHall so that it remains outside the NØ target tube and decay pipe. It will be focused on a target in the 50-m extension of Enclosure 103. This design will solve two long-standing problems related to the operation of the N7/N3 and N7/N5 beamlines. First, the new route will allow the operation of either N7/N5 or N7/N3 independent of the particular target train in the NØ target tube. At present, the N7/N5 beam cannot operate when the dichromatic beam target train is in NØ target tube because the dichromatic beam magnets block the present N7 line. The schedule for February 1981 calls for simultaneous operation of the NØ dichromatic beam and the N7/N3 hadron beam.

The second problem this project solves is the elimination of the restriction on the proton intensity that can be targeted on the N3/N5 target. The intensity has been limited to an average of 5×10^{10} ppp (protons per pulse) on the N3/N5 target because the shielding around Enclosure 100 does not meet the Fermilab standards for groundwater protection. A proton intensity of 5×10^{11} ppp is needed to make the enriched \bar{p} and K^+ beams needed for the 30-in. bubble-chamber experiments 597 and 565. The shielding surrounding the new target location in Enclosure 103 is designed for 10^{12} ppp.

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The earth shielding between Neuhall and Enclosure 100 will be removed from the NØ shield and stored adjacent to the berm. In the vicinity of the upstream 25 m of the NØ target tube, special precautions will be taken because the earth shielding in this location may in part be radioactive. It is planned to store this material separately under controlled conditions so that it cannot become airborne or be accidentally dispersed by the contractor.

A similar plan has been adopted for relocating the N7 beam pipe between the downstream end of Enclosure 101 and the upstream end of Enclosure 103. Portions of the steel pipe between Enclosure 100 and Enclosure 103 will be installed after the completion of the NØ shield.

2. N7 Relocation Costs and Time Schedule

The scope of the project includes: 1) removal of equipment from Enclosure 103 and relocation of earth shielding; 2) acquisition of 1000 m of 40-cm steel pipe; 3) installation of that pipe between Neuhall and Enclosure 103 on the relocated N7 beam line; 4) installation of new beam components and shielding in Neuhall and Enclosure 103 after modifications are complete.

A cost estimate is given in Table III.

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Table III

N7 Relocation Costs

1.	Operating Costs related to site preparation - FY80	
1.1	Optics design and engineering	20K
1.2	Removal of equipment from E 103 and subsequent reinstallation	10K
1.3	Removal of earth shielding between Neuhaus and Enclosure 100, Enclosure 103 and Batavia Road and subsequent restoration	340K
		<hr/>
		370K
2.	Capital Equipment Costs - FY80	
2.1	1000 m of 40-cm iron pipe	100K
2.2	Pipe installation and joints	90K
2.3	Installation of new magnets, dc power cables, and control cables in Neuhaus and Enclosure 103	40K
2.3.1	- Magnet installation	
2.3.2	- dc power cables and control cables	
2.3.3	- Instrumentation	
2.3.4	- Labor (electricians)	
2.4	Acquisition of additional N7 beamline components and instrumentation	60K
2.5	Engineering and Inspection	<u>15K</u>
		305K

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The time schedule is shown in Table IV.

Table IV

Time Schedule for N7 Relocation

1.	Bids prepared for the purchase of the pipe.	March 1, 1980
2.	Begin to remove the earth shielding in the NØ beam between Neuhall and Enclosure 100.	June 15, 1980
3.	Begin to install pipe from Neuhall to Enclosure 101.	July 25, 1980
4.	Finish pipe from Neuhall to end of steel shield (about 101).	August 1, 1980
5.	Begin restoration of earth shield between Neuhall and Enclosure 101.	August 1, 1980
6.	Begin to install pipe from Enclosure 101 to Enclosure 103.	August 15, 1980
7.	Finish pipe from Enclosure 101 to 103. Earth shielding restored between Neuhall and Enclosure 101.	September 15, 1980
8.	Earth shielding restored from Neuhall to Enclosure 103.	September 15, 1980
9.	Complete installation of all magnets in Neuhall and Enclosure 103.	November 1, 1980
10.	Ready for beam in N7.	November 1, 1980

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D. NEUHALL EXTENSION

1. Description of Neuhall Extension

a. Need for the Project. The third project for 1980 is an extension of the NØ neutrino target area in order to accommodate longer dichromatic neutrino trains. Dichromatic neutrino physics has had a long and successful life at Fermilab, beginning with Experiment 21 by the Cal Tech, Fermilab, Rockefeller group and continuing with E356 and E616 by the Cal Tech, Fermilab, Rochester, Rockefeller group. It was clear that a higher-energy, higher-acceptance dichromatic neutrino beam with better energy resolution and smaller wideband backgrounds was needed after the completion of E21 in 1975. Initial target train designs produced the desired increases in energy and acceptance but could not be accommodated in the present NØ target tube, a 65-m long by 1.8-m diameter steel tube located just downstream of Neuhall. A compromise solution was adopted³ that would fit in the target tube and go to higher energies with better acceptance at all energies. Unfortunately, it has the undesirable characteristics that the primary proton beam is dumped inside one of several magnets after it traverses the target. This target train is consequently costly to maintain in terms of both money and radiation exposure to people.

The latter problem is caused by the use of fragile and poorly located proton beam dumps. Because the train can only be 65 m long, the dumps and the magnets must share the same space; it was for this reason that the dumps were put inside the magnets. The magnets have therefore been exposed to extremely high radiation doses. The FY 1980 AIP project entitled "Neutrino Target

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Area Extension" will provide an enclosure long enough for dichromatic trains that do not have these limitations.

b. Conventional Construction. The extension to NeuHall will consist of a 100-m long precast concrete tunnel that will extend from the upstream end of NeuHall to the upstream end of the G-3 Switchyard enclosure, as shown in Fig. 1. It will be 3 m wide and 2.4 m high. It will be surrounded with sufficient shielding to meet the Fermilab standard for groundwater protection when the entire accelerator intensity strikes the designated target or one of the downstream beam elements. The tunnel will be sealed, with shielding doors at its downstream end to minimize the radiation and radioactivity in NeuHall. The combined length of the new tunnel and NeuHall will easily accommodate trains as long as 150 m. This length will permit the construction of higher-energy target trains^{4,5} that can dump the beam cleanly in a single dump without resorting to using magnets as dumps.

The choice of this location provides several distinct advantages. The construction will be in non-radioactive soil. The available decay path for the mesons is approximately 50% longer than the decay path with a train in the present NØ target-tube location, thereby providing more neutrinos per proton. The decay of pions and kaons before momentum selection of the beam leads to undesirable contamination of the neutrino (or anti-neutrino) beams by off-momentum and opposite-sign neutrinos. The primary proton beam is rising at an angle of 10 mrad at G-3 and this angle can be exploited to provide a natural way to achieve the desired condition of minimizing background from

c. Optics. The NØ primary proton-beam transport and target focusing system in NeuHall will be relocated into the extension as part of this project. The NØ/N7 Lambertson magnets will be moved to the upstream end of the new tunnel, where they will deflect the N7 beam eastward by 5.5 mrad to begin the separation of N7 from NØ. The NØ beam will traverse the field-free channel in the Lambertson and continue on to the neutrino target. The two beams thus can follow separate, non-interfering paths to their respective targets.

The 2-cm vertical displacement needed to separate the NØ and N7 beams at the Lambertsons will be provided by a small kicker magnet placed in Enclosure G2. At a later time, this displacement could be achieved by using an electrostatic septum in G2 if operating requirements demanded this condition. Two sets of dipole magnets, B130 and 7BN, provide a 10-mrad downward bend so that the N7 beam exits NeuHall level. Two new B1 magnets and an EPB dipole will be positioned to bend the N7 beam into a new beam pipe connecting NeuHall to Enclosure 100 (see below). Two quadrupoles, 7FN and 7DN, already in NeuHall, will render the beam parallel before it passes through the new pipe to Enclosure 100. The existing NØ proton-beam transport will be reinstalled after the enclosure modifications are complete.

An important property of the new beam transport in the extended NeuHall is that the bypass beam will be deflected to the East of the present NØ beam line. This permits the two beams to reside in the extended NeuHall without interference

between their magnet elements. An even more important property of the new design is that muon backgrounds in the experimental halls from the hadrons in the N7/N3 and N7/N5 beams can be eliminated.

This design cannot be fully implemented until the G-2 extension is completed in FY81. The beam line between the extended NeuHall and Enclosure 103 will, however, be complete by the Fall of 1980. To operate the bypass beam in this period, an interim transport system will be installed in the NeuHall extension and will operate in conjunction with modifications in Switchyard and in the N3/N5 beam line (see Section C).

The vertical bend magnets common to NØ and N7, located in Enclosure C, will be powered from the Switchyard Service Building. The NeuHall parts of the NØ and N7 transports will be powered from the N1 Service Building. At a later time, the NØ vertical bends will be replaced by a new dichromatic target train whenever the NØ line is used for narrow-band neutrino experiments. A complete discussion of these optics is given by R. Stefanski elsewhere⁷.

2. NeuHall Extension Costs and Time Schedule

The scope of this project is to construct a 2.4m x 3m x 100m concrete enclosure with utilities between Switchyard Enclosure G-3 and NeuHall with proper groundwater protection to allow high-intensity operation. The new enclosure will connect G-3 and NeuHall. The project also includes the relocation of the NØ/N7 magnets, septa, and NØ trim magnets into the extension of NeuHall.

Construction cost estimates and schedules are given in Tables V and VI.

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Table V

Neuhall Extension Costs

1.	FY80 Operating Costs Related to Site Preparation	
1.1	Conceptual Design	50K
1.2	Removal of Equipment from Neuhall and G-3	<u>10K</u>
		60K
2.	FY80 AIP Costs	
2.1	Construction of groundwater radiation shield (bathtub)	150K
2.2	Construction of 300-ft concrete enclosure	350K
2.3	Installation utilities and light	50K
2.4	EDIA	<u>50K</u>
	Total FY80 AIP Costs	600K
3.	FY80 Equipment Costs Related to the Project	
3.1	Reinstallation of the NØ beam line in extended Neuhall	<u>10K</u>
	Total Equipment Costs Related to the Project	10K

Table VI

Time Schedule for Neuha11 Extension

1.	Out for bid on precast units	February 20, 1980
2.	Out for bid on construction package	March 15, 1980
3.	Begin fabrication of precast units	April 1, 1980
4.	Begin excavation and demolition of G-3	June 1, 1980
5.	Bulk excavation and fabrication of precast units complete	July 15, 1980
6.	Ground-water shielding and under drains complete. Begin installation of precast units	August 1, 1980
7.	Complete installation of precast units	August 15, 1980
8.	Complete cast-in-place concrete	September 1, 1980
9.	Beneficial occupancy of extended Neuha11	September 15, 1980
10.	Earth shielding restored to 18-ft cover	September 21, 1980
11.	Lambertson magnets in place	November 1, 1980
12.	Ready for beam	November 1, 1980

E. N3 BEAM-LINE MODIFICATIONS

1. Description

The new N3 design² will provide enriched beams of minority hadrons for E-565-570 and E-597 and at the same time preserve the capability of transporting hadrons to neutrino detectors in Lab E and Lab C via the N5 beam. The N5 line and the new N3 line will have a common beam-transport system between Enclosure 103 and 105. Beyond Enclosure 103, the N5 beam will be unchanged except for a slight movement of beam-transport magnets needed to correct for the new target position and angle.

The new N7 primary proton beam will strike the production target in Enclosure 103 with a horizontal angle of 30.8 mrad relative to the NØ line and with a vertical dip angle of -3.4 mrad. The new N3 beam-transport line views the target at a production angle of 3 mrad horizontally and 0 mrad vertically relative to the dipping N7 primary beam. A narrow-aperture EPB dipole following the target provides a vertical upward bend of +3.4 mrad, thereby rendering N3 horizontal. The purpose of this dipole is fourfold: 1) to restrict the momentum bite of the secondary beam entering Enclosure 105; 2) to absorb as many wide-angle low-momentum secondary hadrons as possible before they can decay; 3) to disperse decay muons from secondaries that are not absorbed in the vertical plane; 4) to sweep out the charged particles when the beam is used as a \bar{p} source for E597. By limiting the momentum acceptance of the beam prior to Enclosure 105, it will be possible to minimize the hadron background in the Wonder Building. For the first time simultaneous operation of the N3 beam and experiments in the Wonder Building will be possible.

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By absorbing as many secondaries as possible near the target and by aiming most of the decay muons into the ground, the amount of shielding necessary for radiation protection will be reduced.

The new N3 beam line follows the present N3/N5 trajectory between Enclosure 103 and Enclosure 105. A horizontal bend of ~ 6.5 mrad to the east will be added between two existing quadrupoles in Enclosure 105 to disperse the beam for momentum selection. In addition to momentum collimators, Enclosure 107E contains one horizontal field lens, one vertical field lens, and a west bend of ~ 14 mrad. This is followed by a new Enclosure 108A containing a dipole magnet to bend the beam

~ 7.5 mrad east, matching N3 into the existing downstream pipes and enclosures. Enclosure 108A also contains a quadrupole doublet that makes a dispersion free horizontal and vertical focus about 35 m upstream of Enclosure 112. Collimators at the chromatic foci enable E565/570 and E597 to obtain good-quality enriched beams.

Enclosures 112 and 114 are used without change. Following Enclosure 114, the beam is made parallel for two differential Cerenkov counters. The present Enclosure 106 Cerenkov counter, together with its water jacket will be moved to this location. A second counter will be made by removing the PMT/mirror head presently in Enclosure 108 and connecting it to the pipe connecting Enclosure 114 and the 30-in Bubble Chamber. A final quadrupole is necessary after the second Cerenkov counter to focus the beam horizontally and fan it out vertically as it enters the 30-in chamber.

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2. Cost Estimates for N3 Beam Line Modification

Table VII

Estimated Costs for N3 Beam-Line Modifications

1. Operating Costs - FY80	
Enclosure Relocation	25K
Shielding Installation	20K
Relocation of Buswork and Magnet Moving	<u>20K</u>
Total Operating Costs	65K
2. Equipment Costs - FY80	
Installation of New DC Bus	<u>25K</u>
Total Equipment Costs	25K

F. N5 BEAM LINE IMPROVEMENTS

It is proposed to relocate the N5 beam line in 1981 in order to provide adequate shielding for a full-intensity proton beam to Enclosure 113, to reduce power consumption and to simplify the beam optics. With this improvement, the beam will provide a proton source for the proposed prompt-neutrino target station. The relocated N5 beam will also provide hadrons to calibrate calorimeters for neutrino experiments in Labs B, C, and E. This new beamline will eliminate the large bends (75 mrad) in the present N5 beamline, providing a saving in power and an easy conversion to high-energy operation in the Tevatron era. The beam is shown schematically in Fig 2. Fermilab has requested 610K of FY81 funds for the costs of relocating beam line enclosures and for building new enclosures. Cost estimates for relocating magnets, DC buses, and LCW lines are in preparation. It is planned to carry out the relocation of existing beam line components with FY81 Operating Costs. It is planned to carry out this project during the summer shutdown of 1981.

G. SWITCHYARD G2 ENCLOSURE MODIFICATION

1. Description of Switchyard G2 Enclosure G-2 Modifications

It is proposed to extend the present Switchyard G2 enclosure approximately 40 m north toward Neuhaus during the summer shutdown of 1981. This enclosure will serve as a branch point for the primary proton beams NØ, N7, and the future Mu0 (Muon Beam)^{6,7}. When this project is completed, the proton beam can be steered to one of the following targets: the original NØ target, which will be used by broad band neutrino beams, the new upstream NØ target to be used for high-energy dichromatic beams, and the newly relocated N7 beam, which is the proton source for the N3 and N5 hadron beams. Initially, this will be only a switch that allows the N7 beam and the NØ target to share protons during the spill sequentially. A splitting station is being considered for later installation. This station would allow both beams to operate simultaneously during the spill, rather than sequentially. AIP funds will be used for construction of the new enclosure; operating funds will be used to remove equipment from the enclosure before turning it over to the contractor; equipment funds will be used to refurbish existing beam-line components and to reinstall them after the enclosure is complete.

2. Cost Estimate and Schedules

A cost estimate for the modification to the G-2 enclosure has been prepared and is given in Table VIII.

Table VIII

G-2 Switchyard Modification Costs

1.	FY81 Operating Costs Related to the Project	
1.1	Removal of equipment from G-2 enclosure	20K
1.2	Removal of earth shielding from the G-2 enclosure and the vicinity of G-2 enclosure and restoration after the modification of G-2	50K
1.3	Reinstallation of NØ beam equipment in G-2 enclosure	<u>20K</u>
	FY81 Operating Costs	90K
2.	FY81 AIP Costs (Accelerator Division)	
2.1	Construction of an extension to G-2	200K
2.2	Installation of lights and utilities	30K
2.3	Procurement and Installation of Improved Components	50K
2.4	EDIA	<u>20K</u>
		300K

H. TARGET STATION FOR PROMPT NEUTRINO BEAMS

It has been pointed out that the flux of neutrinos that come from the leptonic or semileptonic decay of particles with lifetimes of less than 10^{-12} seconds is not attenuated by a proton beam dump. On the other hand, the decay paths for pions and kaons produced in a beam dump are about two-thousand times shorter than the decay paths in the standard neutrino beams at Fermilab. For this reason, the neutrino flux emerging from a beam dump will have a much greater fraction of τ neutrinos and e neutrinos than the standard beam. During the past year, considerable progress has been made in the design of beam-dump neutrino sources. Several promising designs exist that appear to reduce the muon flux emerging from the dump to tolerable levels. One of these designs is being implemented in the Meson Area for Experiment E-613. Although the basic properties of a beam dump have been established, specific detector designs that can isolate the τ neutrino in an unambiguous manner have not emerged. In the past year considerable progress has been made toward a feasible detector design. In particular, the use of the 15-ft bubble chamber appears promising. For these reasons, the Laboratory is now considering the design of an enclosure to provide a prompt-neutrino source.

It will be possible to build in 1983 an enclosure for a magnetized iron beam dump and muon shield upstream of Lab E. It can be used by the detectors located in Lab B, C, and E. The beam dump target would be illuminated by primary protons transported through the relocated N7/N5 line. This project will include

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pretarget magnets that steer the beam onto the target at the desired angle, and a magnetically active beam dump. The beam dump will consist of a magnetic iron shield approximately 35 m long followed by a 65-m passive-iron shield. The iron shields detectors and experimenters from muons originating from hadron decays in the beam dump. A possible schematic of this installation is shown in Fig 2. At this time, specific designs of a magnetized steel beam dump are being reviewed in order to evaluate their feasibility.

If built, the area could be used at 500 GeV/c and, with a suitable upgrading of the magnets and shielding, serve at 800 or 1000 GeV/c. A preliminary estimate of \$700K construction funds (AIP) required for this project has been made.

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I. NEUTRINO FLUX MONITORING

A significant shortcoming of the Fermilab wide-band beam neutrino experiments has been the inability to measure the neutrino flux incident upon the experimental detector apparatus. The principal reason for this was the inhomogeneous muon shield. The NØ muon-shield upgrade will eliminate this problem and will in addition provide for three and perhaps four monitoring stations that can be utilized to provide information on neutrino flux. As presently envisioned, the neutrino-flux monitoring system will consist of three stations, each equipped with a 6-ft by 6-ft segmented-wire ionization chamber and a total-intensity ion chamber to give information on the total muon flux intensity and on the shape of the muon distribution in x and y . The necessary digitizers to integrate the total flux intensity and the SWIC readouts have already been developed and used successfully in connection with the dichromatic-beam flux-monitoring program. The first two monitoring stations will be located inside the existing Enclosure 100, after 4 m and 15 m of steel, respectively. The third station will be located in one of the crossovers of Enclosure 101 reserved for this purpose during the steel installation. This station will be about 120 m into the shield. A fourth station could be added at a point roughly 60 m into the steel, if this appears to be desirable. Calculations are proceeding to determine whether it will be needed for 500 GeV operation. This project will be supported by FY81 equipment funds. The total incremental costs of the project will not exceed \$60K.

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J. SUMMARY OF PROJECTED COSTS OF THE 1980 SUMMER SHUTDOWN PROJECTS

Operating Costs (exclusive of direct salaries)

NØ muon shield hardening	355K
N7 relocation	350K
Neuhall Extension	10K
N3 Modifications	<u>65K</u>
	780K

Capital Equipment Costs (exclusive of direct salaries)

NØ muon shield hardening	0K
N7 relocation	305K
Neuhall Extension	10K
N3 modifications	<u>25K</u>
	340K

Accelerator Improvement Costs

NØ Muon shield hardening (FY79)	700K
Neuhall Extension (FY80)	<u>600K</u>
	1300K

Operating Salaries	70K
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Equipment Salaries	<u>50K</u>
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Total of Projected Costs (FY78, FY79, FY80)	2540K
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K. FUTURE OPTIONS

One option for the future which is in the planning stage is the construction of a 750-GeV dichromatic train that can be used to provide dichromatic neutrino beams in the energy range between 350 GeV and 700 GeV. It is expected that protons of 700 GeV or more will be available in 1983 and it is proposed to begin the construction of such a train in 1981. This train will utilize the new target area constructed in 1980. At present one potential design exists⁴ and another is being designed⁵. The new train will be optimized for high energy tunes greater than 500 GeV/c with 800-GeV or 1000-GeV incident protons and will feature clean dumping of the proton beam. Since at higher energies neutrino energy resolution depends strongly on angular divergence of secondary particles, the angular acceptance of this high-energy train will be limited. Because of this limited acceptance, the present D30 train³ will continue to be used if neutrino energies below 350 GeV/c are desired.

The projects discussed thus far were all designed with 1000 GeV in mind. The application to 500 GeV was achieved by cutting the amounts of shielding back to correspond to the lower energy or by decreasing the number of magnetic elements in a beamline. All construction projects can be used with no further changes. Below we give the general elements for further upgrading to 1000-GeV operation:

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- a. NØ Muon Shield: Add 100 m of steel to the previously installed 150 meter shield. Fill in the NØ earth shield at the Wonder Building.
- b. N7 Relocation: Utilize new switch in Enclosure G2 and strengthen all magnetic bends.
- c. NeuHall Extension: No changes are needed.
- d. N3 Beamline: This beamline will be decommissioned after the completion of the 400 GeV 30-in Bubble Chamber Program.
- e. N5 Beamline: Strengthen magnetic bends as needed.
- f. High-Energy Dichromatic Beam: A 700-GeV train will be constructed.
- g. Enclosure G-2 Extension: Strengthen magnetic elements.
- h. Target Station for Prompt-Neutrino Source: Strengthen magnetic bends and increase passive shield.
- i. Neutrino Flux Monitoring: Add one more monitoring station.

References

1. S. Mori, TM-790, TM-843
2. A. Malensek. TM-940
3. D30 Train, TM-661
4. L. Studde, TM-841 A
5. R. Stefanski, private communication
6. Evans and Kirk - Switchyard TM-796
7. R. Stefanski, TM-934, TM-937

Figures

1. Neutrino Area - Fall 1980
2. Neutrino Area - Fall 1982

Figure 1: Schematic of Neutrino Area.
 Fall 1980 after completion of
 Target Hall Addition, N-O muon
 shield upgrade, and N-7 relocation.

NOTE: 50:1 distortion of horizontal and vertical scales

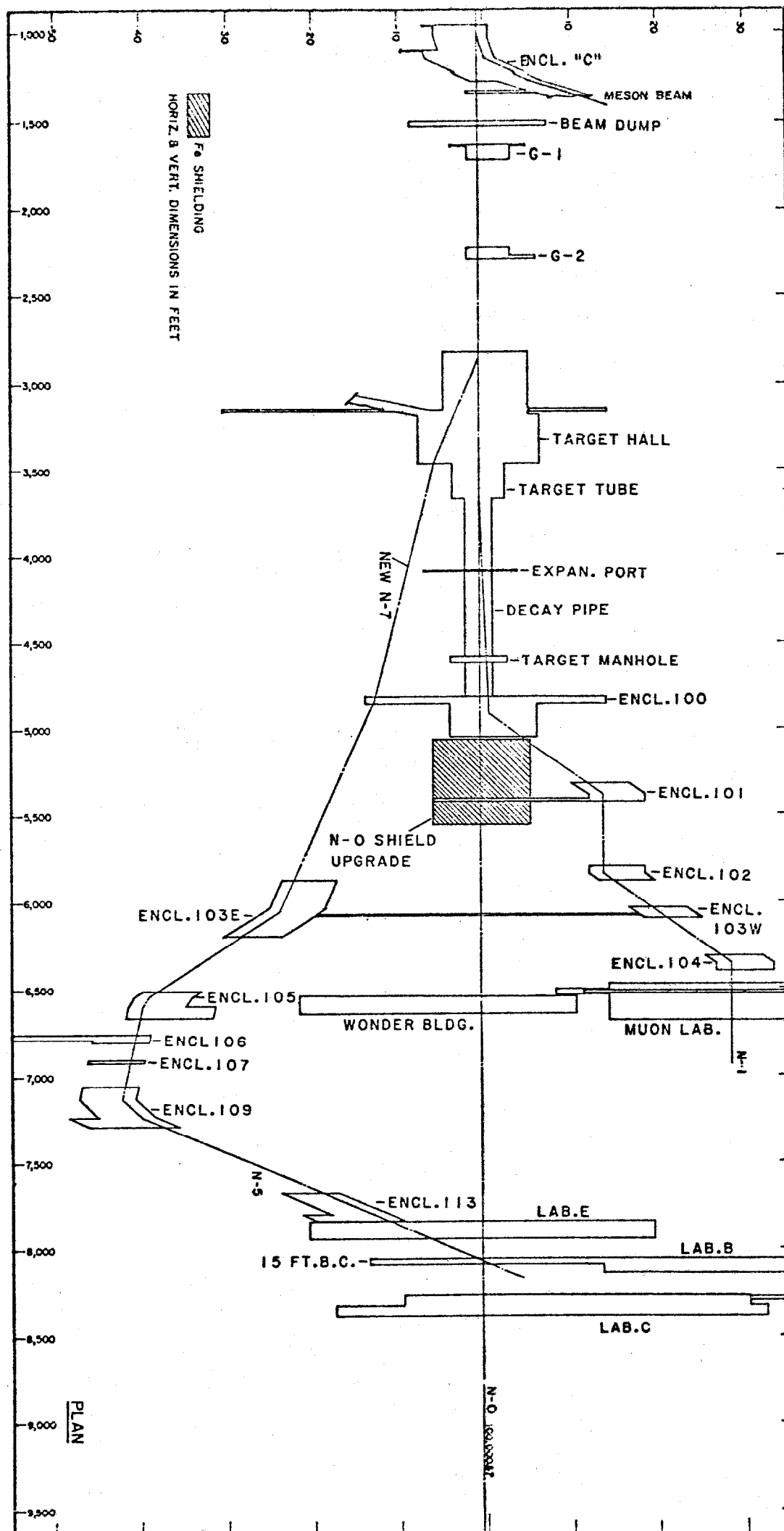


Figure 2: Schematic of Neutrino Area .
 Fall 1982 after completion of
 G-2 Addition, N3/N5 relocation,
 and construction of beam dump
 for prompt neutrino source.

NOTE: 50:1 distortion of horizontal and vertical scales.

